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(NASA-CR-176277) VISUAL INFORMATION TRANSFER. PART 1: ASSESSMENT OF SPECIFIC INFORMATION NEEDS. PART 2: PARAMETERS OF APPROPRIATE INSTRUMENT SCANNING BEHAVIOR Progress Report, 15 Feb. - 15 (Old Dominion

N86-11850

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G3/53 27615

VISUAL INFORMATION TRANSFER: I. ASSESSMENT OF SPECIFIC INFORMATION NEEDS II. PARAMETERS OF APPROPRIATE INSTRUMENT SCANNING BEHAVIOR

By

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Progress Report
For the period February 15, 1985 to October 15, 1985

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Grant No. NAG-1-451
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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
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October 1985

EYE-SCAN BEHAVIOR IN A FLIGHT SIMULATION TASK

AS A FUNCTION OF LEVEL OF TRAINING

Research Objective:

The present study explored eye-scan behavior as a function of level of subject training. The initial phase of the research involved the development of a suitable task that was representative of that performed by pilots, yet had the necessary characteristics to make research on instrument scanning feasible. The second phase of the research involved data collection to refine the task and to collect standardization data. The third phase consisted of data collection with simultaneous measurement of task performance and scanning behavior as initially naive subjects practiced the task and developed skill.

Approach:

The flight simulaton task employed in the study was presented on a desk-top microcomputer, and was a simulation of some of the tasks performed by aircraft pilots under instrument flight conditions. Subjects monitored and controlled the heading, altitude, rate of ascent/descent, speed, and attitude (pitch and roll) of the simulated aircraft. During specified times during each ten-minute trial, instructions were given to approach a new heading, a new altitude, or to land the aircraft. Task performance data was recorded at intervals of 1/10th second. Concurrent eye-movement data was collected at intervals of 1/30th second, by a second microcomputer dedicated to the task of oculometer data reduction. The type and time of occurence of task instructions and subject control responses were recorded by the data reduction microcomputer.

Progress to Date:

Preliminary results of the study were reported in a paper presented at the Annual Meeting of the Human Factors Society, Baltimore Maryland on October 1, 1985. This paper appears in the Proceedings of the Annual Meeting of the Human Factors Society, and a copy of this paper is attached.

Future Plans:

Testing of subjects in increased "workload" situations is planned. Such test conditions will permit an examination of eye-scan during situations in which tasks must be "shed" in order to accomplish the central or most important task.

EYE-SCAN BEHAVIOR IN A FLIGHT SIMULATION TASK AS A FUNCTION OF LEVEL OF TRAINING

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ABSTRACT

The present study explored eye-scan behavior as a function of level of subject training. Oculometric (eye-scan) measures were recorded from each of ten subjects during training trials on a CRT-based flight simulation task. The task developed for the study incorporated subtasks representative of specific activities performed by pilots, but which could be performed at asymptotic levels within relatively short periods of training. Changes in eye-scan behavior were examined as initially untrained subjects developed skill in the task. Eye-scan predictors of performance on the task were found. Examination of eye-scan in proximity to selected task events revealed differences in the distribution of looks at the instruments as a function of level of training.

INTRODUCTION

Among the variables that are important to an understanding of how pilots obtain information from scanning aircraft instruments, and to forming a basis for improved designs of such information display systems, is an understanding of what constitutes "good" and "poor" scanning behavior on the part of the pilot. One approach to developing an understanding of what constitutes good versus poor scanning behavior is to study changes in scanning as initially untrained subjects develop skill in a flight simulation task. Because research to date on aircraft instrument scanning has generally utilized highly trained pilots with highly developed skills and little variation in skill from one to another, there has been little opportunity to examine changes in eye-scan as a function of level of training.

The initial objective of the present study was to develop a task that employed the types of activities required of an operational aircraft pilot, but which could be presented less expensively and learned more quickly. A requirement of the task was that asymptotic levels of performance could be achieved within relatively short periods of training. After developing such a task, secondary objectives were (1) to study the evolution of eye-scan behavior from the initial exposure to the task to the eventual asymptotic level of performance, and (2) to determine if there are eye-scan behavior correlates of subject performance on the task.

The conceptual basis of the present study is an "error-dependent model of instrument scanning behavior" (Jones, 1983). This model was the product of prior research on the instrument scanning behavior of commercial airline pilots. Briefly, the model assumes that the scanning behavior of the pilot is driven by the pilot's knowledge of the desired state of the aircraft (based on experience and training) and the pilot's attempt to reduce the discrepancy between the actual state of the aircraft and the desired state of the aircraft. Therefore, instrument scanning represents an attempt to obtain information that may indicate (1) that the actual state of the aircraft does not deviate from the desired state enough to warrant corrective action, or (2) that the actual state deviates from the desired state by a certain direction and magnitude.

In the case of a deviation between actual and desired states, pilot control responses are initiated which then shift eye-scan behavior, according to the

model, to a confirmatory loop in which eye-scan is driven by the need for information confirming that the control response was in fact an action that would reduce the deviation between actual and desired states. It would be expected that novice subjects, having little experience or training, would initially exhibit eye-scan behavior that is more information gathering and hypothesis testing than would be seen in these same subjects after increased levels of training and experience.

METHODOLOGY

Subjects and Method

A total of 10 undergraduate college students performed a simulated flight task by "flying" a total of 25, ten-minute flights (trials) over five consecutive days. On the initial day, each subject received a brief standardized description of the purpose of the experiment, a description of the oculometer, and its purpose, and identification of the relatively unobtrusive recording equipment adjacent to the task computer in the subject's room. The subject was then presented with a standardized description of the task, the flight plan, and detailed descriptions of the control mechanisms for the computer based flight simulation. A practice trial was then presented to the subject (without heading or altitude instructions) during which the subject had an opportunity to manipulate and observe the result of each of the simulation controls. After the practice trial, and the answering any question the subject might have regarding the task, the first of the 25 training trials began. Rest breaks of approximately three minutes duration were observed at the conclusion of each trial.

The design of the experiment permitted within-subject assessment of performance and eye-scan data. The within-subject data permits examination of eye-scan during conditions of good and poor performance by the same individual, enabling changes in eye-scan with level of training on the task to be evaluated.

Flight Simulation Task

The flight simulation task utilized in the present study was designed to provide subtasks representative of specific tasks performed by pilots. The flight simulation task was CRT based, and was presented on a desk-top micro-computer (Zenith Z-89), and permitted subjects to monitor and control the heading, altitude, rate of climb/descent, speed, and attitude of the simulated aircraft. During specified times during each ten-minute trial, instructions were given (analogous to Air Traffic Control communications) to change headings or altitude, or to land the aircraft. These instructions were issued through instruction boxes on the CRT display. The instruction box for a particular flight parameter, such as heading or altitude, was located on the opposite side of the CRT display from the corresponding indicator, in order (1) to reduce the role of peripheral vision during performance of the task, and (2) to make eye movements between an indicator and its corresponding instruction box easy to spot in the oculometric data. In addition to the instruction boxes, there was a "Warning Box" which presented a warning such as "SPEED TOO LOW", if a particular flight parameter greatly exceeded normal bounds.

Task performance data on six dependent measures were recorded at intervals of 0.1 second. These measures include (1) Heading change performance, (2) Altitude change performance, (3) Landing performance, (4) Airspeed during heading change, (5) Airspeed during altitude change, and (6) Airspeed during landing. These six measures were available as individual performance measures or they could be combined into a single composite performance measure.

Measurement of eye movement

Eye movement was measured using the corneal reflection technique. This technique allows unobtrusive measurement of eye lookpoint while permitting subject head movement over approximately one cubic foot of space. Details of the technology of the instrument may be found in Merchant and Morrisette (1974). Specifications of the system used in the present study, a NASA Langley Research Center modified Honeywell Mark III, may be found in Spady (1978). A review of various techniques of eye movement recording, and typical applications, may be found in Young and Sheena (1975).

Oculometer data was recorded on a second micro-computer at a sampling rate of 1/30 second (oculometer video frame update rate). The second micro-computer was connected to the flight task computer and in addition to oculometer data also recorded the time and type of

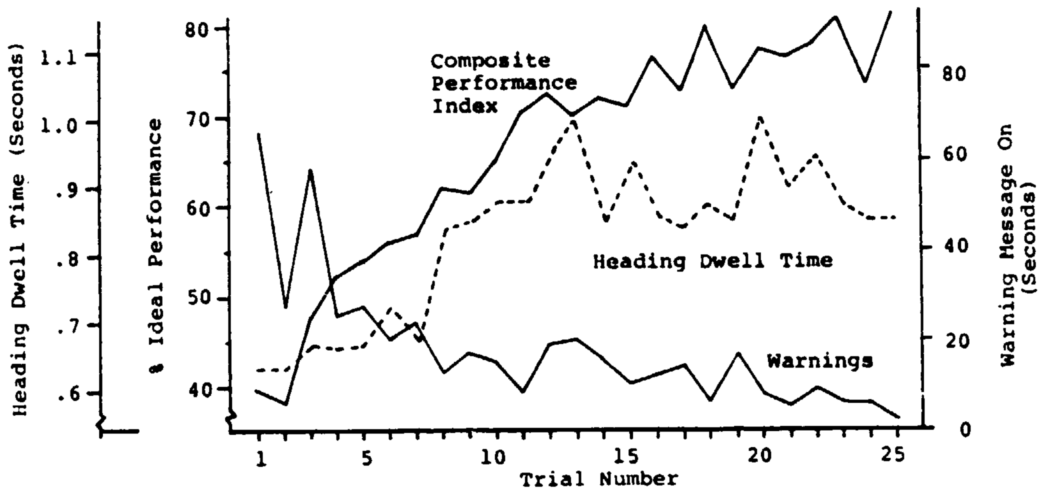

Figure 1: Task Performance, Heading Indicator Dwell Time, and Warning Messages as a function of level of training

each instruction issued to the subject, and the time and type of each subject control response. This permitted subsequent examination of eye-scan behavior related to specific task instructions or control responses.

RESULTS AND DISCUSSION

Analyses of eye movement data may be conducted in various ways, making it imperative that terms and measures are carefully defined. For the present study "dwell time" was defined as the time the eyes spend within the boundaries of a particular instrument, before moving on (saccade) to another instrument.

In addition, eye movement data may be analyzed either by examining "global" measures such as dwell times on each instrument during a particular trial or portion of a trial, or by examining the data selectively at specific points or events in the flight simulation task. The results presented here are based on both global and selective measures of eye-scan behavior.

Predictors of task performance

Performance measures presented as a function of the number of trials reveals that the task is a sensitive measure of complex performance that approaches asymptotic levels by the 25th trial. Figure 1 shows the composite measure of task performance over 25 trials, the amount of time spent with a task "Warning Message", and the average dwell time on the Heading Indicator. Heading Indicator dwell time is presented in the figure as it was the global eye movement measure with the highest simple correlation with the task composite performance measure for the combined data of all ten subjects.

Using dwell times on the indicators and instruction boxes on the CRT based flight simulation task as predictors of the task composite performance measure in multiple regression analyses, a Multiple R of .94 is found for the combined data of the ten subjects over the 25 trials. If regression equations are derived separately for each of the subjects, based on one individual's dwell times and rate of dwells and his or her composite performance index, the picture is more complicated, as subjects do not share the same set of predictors. The failure to find consistent predictors using global measures of eye scan suggests that other measures be explored. These measures include examination of sequences of dwells on the instruments, and the time required for the performance of these sequences (These measures are currently being explored but are not available for the present report).

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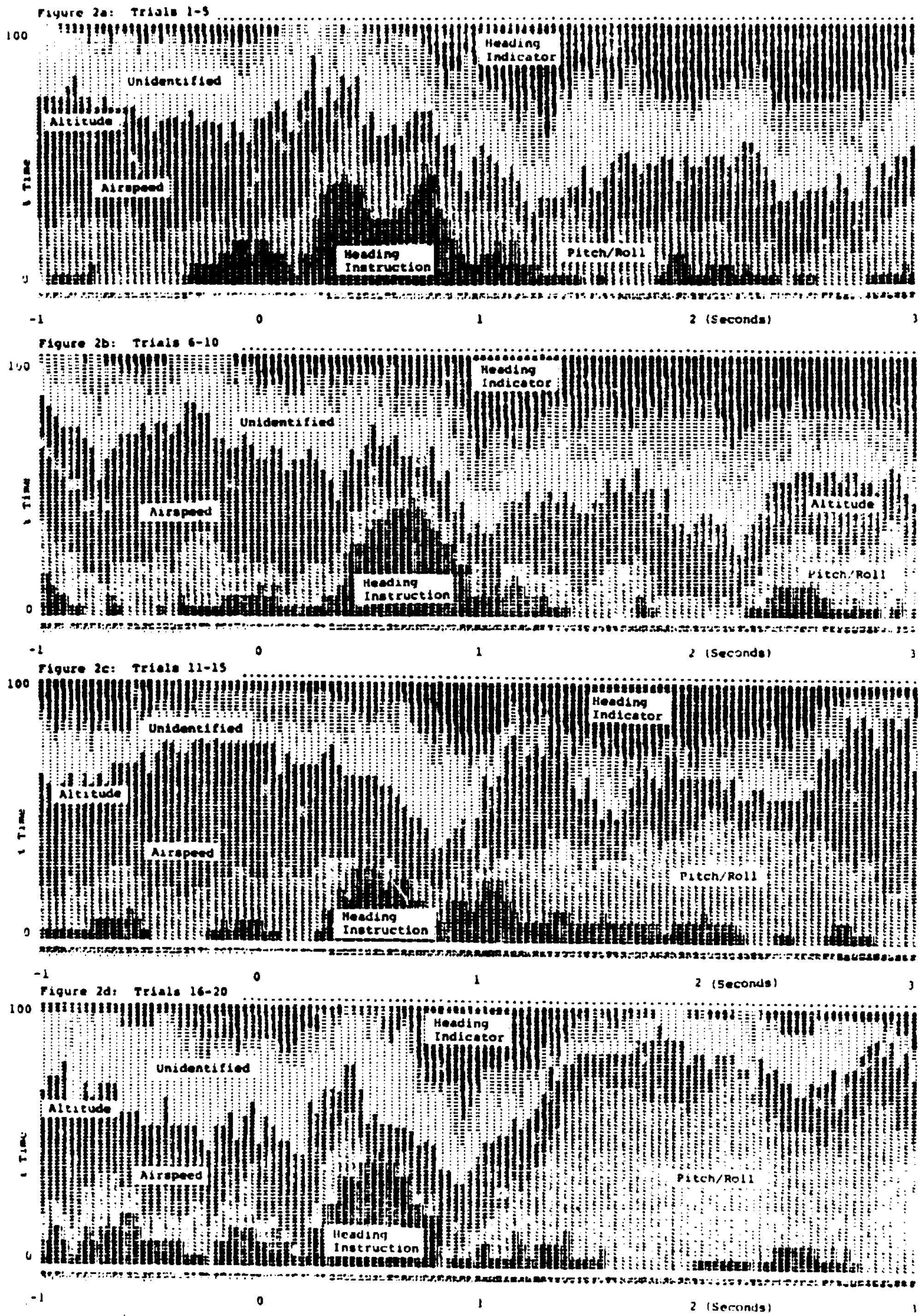

Figure 2: Time-Locked Time-Histories

Time-Locked Time-Histories

Figure 2 presents a new way of looking at eye-scan information. These plots are labelled time-locked time-histories as they illustrate where the subject was looking during a period of time before and after a certain time-locking event. The time-locking event for the time histories shown in figure 2 was the presentation of a new heading instruction. Time "0" is when this instruction was issued, and time "1" represents 1 second after the event. The gray bands on the vertical scale represent percentage of time spent looking at each instrument over a number of occurrences of the time-locking event. The total vertical heighth at a given point corresponds to 100 percent. A wide gray band would mean that a high percentage of time was spent looking at a particular point during the time locking event interval, a narrow band indicates a low percentage of looks at a particular place at a particular point in time. Since there were only five new heading instructions per trial, each of the time histories shown in figure 2 was based on combining five trials for a total of 25 occurrences of the time-locking event.

The panel of figures 2a through 2d show the time-locked time-histories for one subject for increased levels of training. As shown in figure 2a, in response to a new heading instruction this subject showed an increase in looks at the heading instruction box, followed by an increase in looks at the heading indicator. Also in figure 2a, the continued presence of dwells on the heading indicator probably reflect multiple looks at this display to insure that it is changing in the desired direction. Continued looks at the heading indicator diminish with increased training, as can be seen by comparing figures 2a through 2d.

Perhaps the most noticeable change with training level is the increase in looks at the Pitch/Roll indicator following a heading change instruction. The subject, with experience, learns that a change in heading requires a change in both pitch and roll. Methods of quantifying the changes in eye-scan behavior during time-locked events are currently being explored.

GENERAL DISCUSSION

The results of the present study show changes in eye-scan behavior as a function of level of training. These changes are revealed in both global and specific measures of eye-scan. Average dwell time, for example, showed a consistent increase with increased training. Examination of eye-scan in proximity to selected task events revealed differences in the distribution of looks at the instruments as a function of level of training (this is shown in Figure 2).

The capability of identifying eye-scan behavior as varying in quality has important potential for establishing criteria against which to evaluate different information displays, for improving pilot training programs, and may offer some possibility for improved selection of pilot training candidates. The development and utilization of new task-sensitive eye-scan measures may permit addressing these problems.

ACKNOWLEDGMENTS

This project was sponsored by NASA Research Grant NAG-1-451. Thanks are extended to Dr. Randall L. Harris, Sr., the project monitor at the NASA Langley Research Center.

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ASSESSMENT OF SPECIFIC INFORMATION NEEDS COMPLETED

Research Objective:

The initial experiment concerned the assessment of transfer of visual information from cockpit displays to the flight crew as measured by oculometric techniques. Given that the time spent viewing a display may vary depending on the nature of the information sought by the pilot examining the display, this experiment permitted an evaluation of time on the display in response to varied tasks requiring the pilot (1) to confirm indicator or needle position, (2) to determine if the indicated value is changing or not, or (3) to determine change of rate of the indicated value. The design of the function of new displays and display technologies can be facilitated only through an understanding of the nature of the information presented in these displays.

Approach:

The initial experiment was conducted using the ATC-510 desk-top fixed-base simulator located at the NASA Langley Research Center. In addition to the primary flight instruments employed in the simulation, a secondary task was employed using an additional electromechanical display situated along the right side of the simulator panel. For the test subjects, the task was to fly the simulator on a heading of 60 degrees and at an altitude of 3160 feet, while simultaneously performing the secondary task. The secondary task involved extracting selected information from the secondary task display, and responding by a pushbutton located on the simulator "wheel".

Progress to Date:

Data collection for the initial study has been completed. A report on the findings of the study is in preparation.

STUDY OF EYE-DIRECTED COMPUTER INPUT TECHNIQUES COMPLETED

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September 13, 1985
RTOP 505-35-33

Research Objectives

Although the interface between the pilot and his vehicle is becoming more complex with each new airplane design, it is not inconceivable to think that one approach to interface simplification would put the pilot of tomorrow at a desk with nothing but input/output (I/O) devices, flight controllers and a large graphic display linked to the aircraft computer system. Computer manufacturers are constantly trying new techniques to improve the communications interface between the operator and the computer. Such I/O candidates as keyboards, joysticks, trackballs, voice, and mouses are being implemented and studied. Many of these candidates may be applicable to the flight environment, however, with the exception of voice, they each have the disadvantage that hand movement is required. One technique of input which leaves the hands free to do other types of tasks is currently being explored by LaRC. This technique is the use of eye-directed computer input (display menu selection) and it is being studied under research grant at the Old Dominion University.

Approach

In order to compare eye-directed input with a "best case" (hand directly on the keypad) keyboard entry system, 4-choice and 12-choice visual search tasks were designed and evaluated. Langley's oculometer system was used to track subjects lookpoints during a menu selection task. A microcomputer was used to present to the subject a menu and the item to be selected by eye position. The accompanying figure shows the format of the CRT-based 12-choice search task. The dashed lines within box 4 on the figure show where the subject is looking. These lines are analogous to the traditional "cursor", except that this cursor is eye-directed and requires no hand movement by the subject to move it from place to place. The selection of an item from a menu is therefore reduced to the pressing of a single button and could be implemented, at a future date, entirely by eye movement.

Accomplishment Description

The results of the preliminary study showed that the use of eye-directed inputs made the selection process significantly faster in both 4- and 12-choice visual search tasks. The faster response times with eye-directed input were found when comparing "best case" keyboard inputs (hand directly on keypad) with eye-directed input. The time saved by eye-directed input was shown to be greater when the menu incorporates a greater number of items. The use of eye-directed inputs is hypothesized to have a psychological advantage over other input devices in that it provides the user with a sense of enhanced control over the machine, because the machine appears to respond immediately to the user's intentions.

Future Plans

It is planned that future research will extend the eye-directed input technique to permit 100 percent eye-directed input (no push-button required for selection entry) and that the eye-directed technique will be compared with other input techniques such as voice, trackball, or mouse. These studies will investigate both speed and accuracy of responses. Further, plans are being made to move the eye-directed input technique into a flight simulator environment to determine its efficacy for selected operational tasks.

STUDY OF EYE-DIRECTED COMPUTER INPUT TECHNIQUES COMPLETED

RESEARCH OBJECTIVES

- o ASSESS THE POTENTIAL OF "HANDS-FREE" METHODS FOR DISPLAY MODE SELECTION AND DATA ENTRY FOR FUTURE FLIGHT DECKS
- o DETERMINE THE SPEED/ACCURACY EFFECTS OF EYE-DIRECTED INPUT CONTROL COMPARED TO OTHER INPUT DEVICES

APPROACH

- o INTERFACE LANGLEY OCULOMETER TO A COMPUTER MENU SELECTION TASK
- o COMPARE REACTION TIME OF EYE-DIRECTED INPUTS WITH KEYBOARD INPUTS

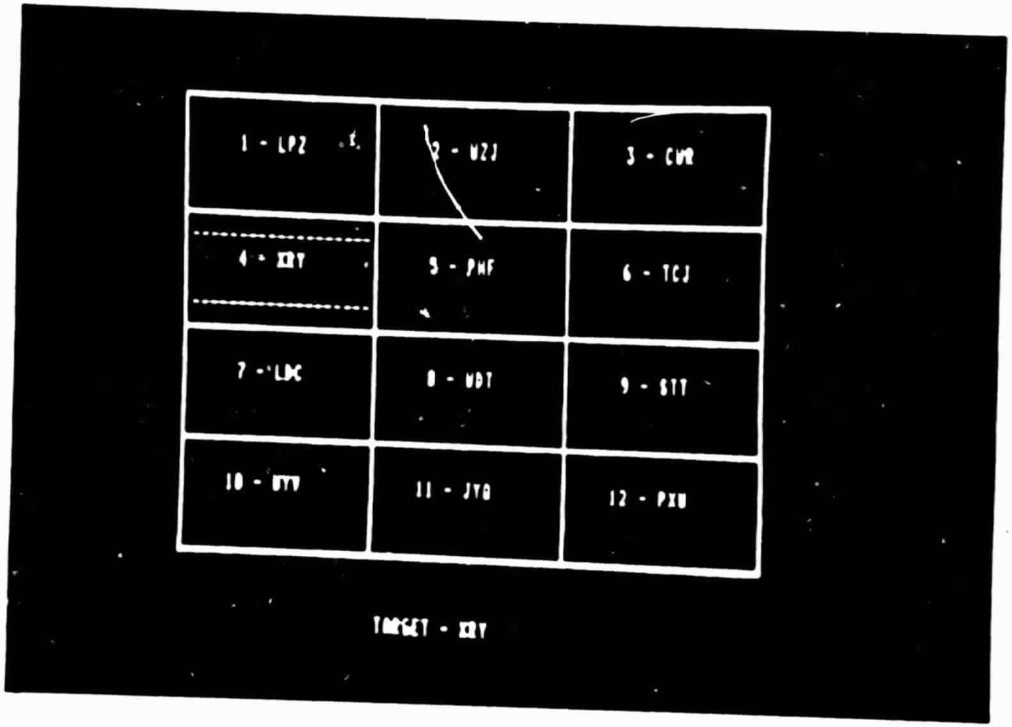
ACCOMPLISHMENT DESCRIPTION

- o PRELIMINARY STUDY COMPLETED USING 4-CHOICE & 12-CHOICE MENUS
  - EYE-DIRECTED INPUTS ARE FASTER THAN KEYBOARD INPUTS
  - TIME SAVED IS GREATER FOR THE LARGER-ITEM MENU
  - EYE-DIRECTED INPUTS MAY PROVIDE USER WITH A SENSE OF ENHANCED CONTROL

FUTURE PLANS

- o EXTEND THE TECHNIQUE TO PERMIT 100 PERCENT EYE-DIRECTED SELECTION (NO PUSH-BUTTON REQUIRED FOR SELECTION ENTRY)
- o COMPARE EYE-DIRECTED TECHNIQUE VERSUS OTHER I/O TECHNIQUES
- o ASSESS THE UTILITY OF EYE-DIRECTED CONTROL IN A FLIGHT SIMULATOR ENVIRONMENT

STUDY OF EYE-DIRECTED COMPUTER INPUT TECHNIQUES COMPLETED



EYE-DIRECTED MENU SELECTION (BOX 4 BEING VIEWED BY TEST SUBJECT)